TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Autonomous Mobility Appliqué System (AMAS)

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Report Documentation Page

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TARDEC – Who We Are

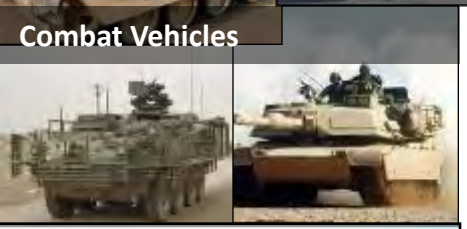

Combat Vehicles


Heavy Tactical Vehicle


Medium Tactical Vehicle


Light Tactical Vehicle


Countermine Equipment



MISSION: Provide full service life cycle engineering support to our TACOM LCMC customers (PEO GCS, PEO CS&CSS, ILSC) and PM FCS (BCT), to develop and integrate the right technology solutions to improve the effectiveness of the current force and realize the superior capability of the future force to facilitate army transformation.

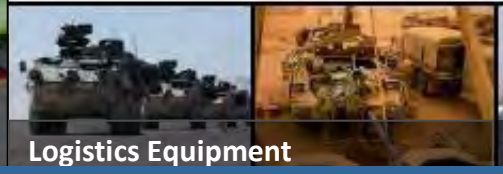
VISION: Be the first choice of technology and engineering expertise for ground vehicle systems and support equipment - today and tomorrow.

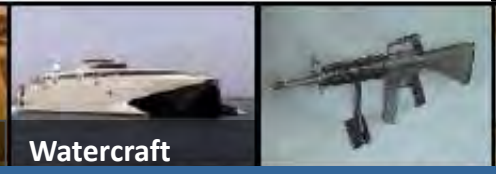

Trailers


Military Bridging


Water Generation and Purification


Fuel and Water Storage & Distribution Quality Surveillance Equipment


Logistics Equipment


Watercraft

TARDEC is responsible for research, development and engineering support to more than **2,800** Army systems and many of the Army's and DoD's top joint warfighter development programs.

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

How To Speak Army Robotics

TLA – Three Letter Acronym

UPI - UGCV (Unmanned Ground Combat Vehicle) PerceptOR (Perception for Off Road) Integration

Passive Safety – Vehicle features that warn/notify the drive, but do not control the vehicle

Active Safety – Vehicle features that augment the drives capabilities (braking, accelerating, steering)

Scalable Autonomy – With the turn of a knob to be able to select on the fly how autonomous a vehicle will perform

Robot – A ground, air, sea or underwater platform that can perform tasks remotely with or without human supervision.

OMV – Optional Manned Vehicle

Convoy Operations Can Be Dangerous for Different Reasons

- Major accidents due to driver error
  - Very long convoy missions—10 to 14 hours
  - Difficult, unpaved, rugged terrain
  - Inexperienced drivers—age 18 & 19 years
  - Collision(Front & Rear), Rollover, Roadway Departure, etc.
- Susceptibility to attack by adversary
  - Asymmetric warfare
    - Improvised explosive devices (IEDs)
    - Coordinated threat attack

What is AMAS

AMAS will provide scalable autonomy in a single material solution agnostic of vehicle. For the AMAS JCTD, AMAS will be implemented in a vehicle specific By-wire kit that would provide the electronically controlled subsystems and interface for the common Autonomy Kit. The Autonomy kit, along with the By-wire kit, would provide Leader/Follower, waypoint navigation and advanced Convoy behaviors.

The AMAS JCTD will also address defining an open architecture for future autonomy enhancements. Along with Analysis of Alternatives for testing large unmanned ground vehicles (UGVs).

By-Wire Kit

- ***By Wire Kit - Active Safety and Control Interface***
  - *Configuration:* Install Hardware and Software necessary to provide Active Safety Capability and Interface/Control of the Steering, Braking, Transmission, and Engine functions of the vehicle. Kit will be Interfaced Electronically and not Interfere with Egress/Ingress of Operator.
  - *Problems addressed:* Prevent accidents through rollover and yaw stability (Over/Under steer) control, collision warning and mitigation, emergency brake, lane keeping; Reduce fatigue through Adaptive Cruise Control (ACC); Provide Interface to control the vehicle which would provide for future upgrades of robotic technology as needed. Current TRL: 6-7
  - *Advantages:*

    Active Safety – Collision Mitigation, Stability Control, Emergency Braking, Adaptive Cruise Control, Roadway Departure Prevention
    1. 26% to 59% Reduction in Truck Related Accidents[1]
    2. Improved Handling due to Stability Control
    3. Decrease in Physical Load on Operator

    Common Interface
    1. Vehicle Gateway/Control for Scalable Robotics(Autonomy Kit Interface)
    2. Enabling Increase in Future Capability

Autonomy Kit

- ***Autonomy Kit – Convoy Capability***
  - *Configuration:* Interface with By-Wire Kit and provide Leader/Follower, Waypoint Navigation, and Obstacle Detection/Avoidance Features to implement a Convoy Capability that can be operated in a Manned or Unmanned Mode.
  - *Problems addressed:* Save lives and increase combat power and situational awareness through semi-autonomous convoy operations; Reduce accidents through obstacle detection/avoidance, road keeping (unpaved), and night vision enhancement; Save fuel in convoy operations; Support logistics operations. Current TRL: 5-6
  - *Advantages:*
    - **Fuel Savings -**7% or more in Unmanned/Manned Mode due to Optimized and Fuel Efficient Automated Driving Cycles. (Eliminates Human Variability Between Drivers)
    - **Increased Night Ops and OpTempo**
    - **Manned** - Driving is automated and Operator can Manually Override.
      1. Decreased Mental Load
      2. Increased Situational Awareness due to Driving Cognitive Load Reduction
      3. Further Decrease in physical Load on Driver
      4. Force Multiplier - Ability to decrease Manning in Vehicles and Reassign
      5. Estimated 2.5 Billion Dollars in net Savings for the Army due to Reduction in Force Structure for Convoy Operations[2]
    - **Unmanned Mode** - Every Other Vehicle in Convoy Unmanned.
      1. Significant decrease in Casualties caused by Accidents and IEDs[6]
      2. Estimated 3.7 Billion dollars in Net Savings for the Army due to reduction in Force Structure[2]

Mission Payload Kit

?

Mission Specific Sensors

?

Mission Specific Software (Processing HW if needed)

?

Mission Specific Actuators

General Autonomy/Leader-Follower Kit

Lidar

Autonomy Computer

GPS Antenna

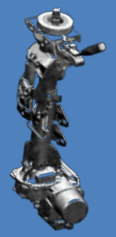
Comm Antenna

By-Wire/Active Safety Kit

Stereo Camera

Forward Automotive Radar

Side/Rear Radar x2



Electric Power Assist Steering (EPAS)
Steering Position Sensor
Steering Torque Sensor

Gateway Controller

Transmission Controller

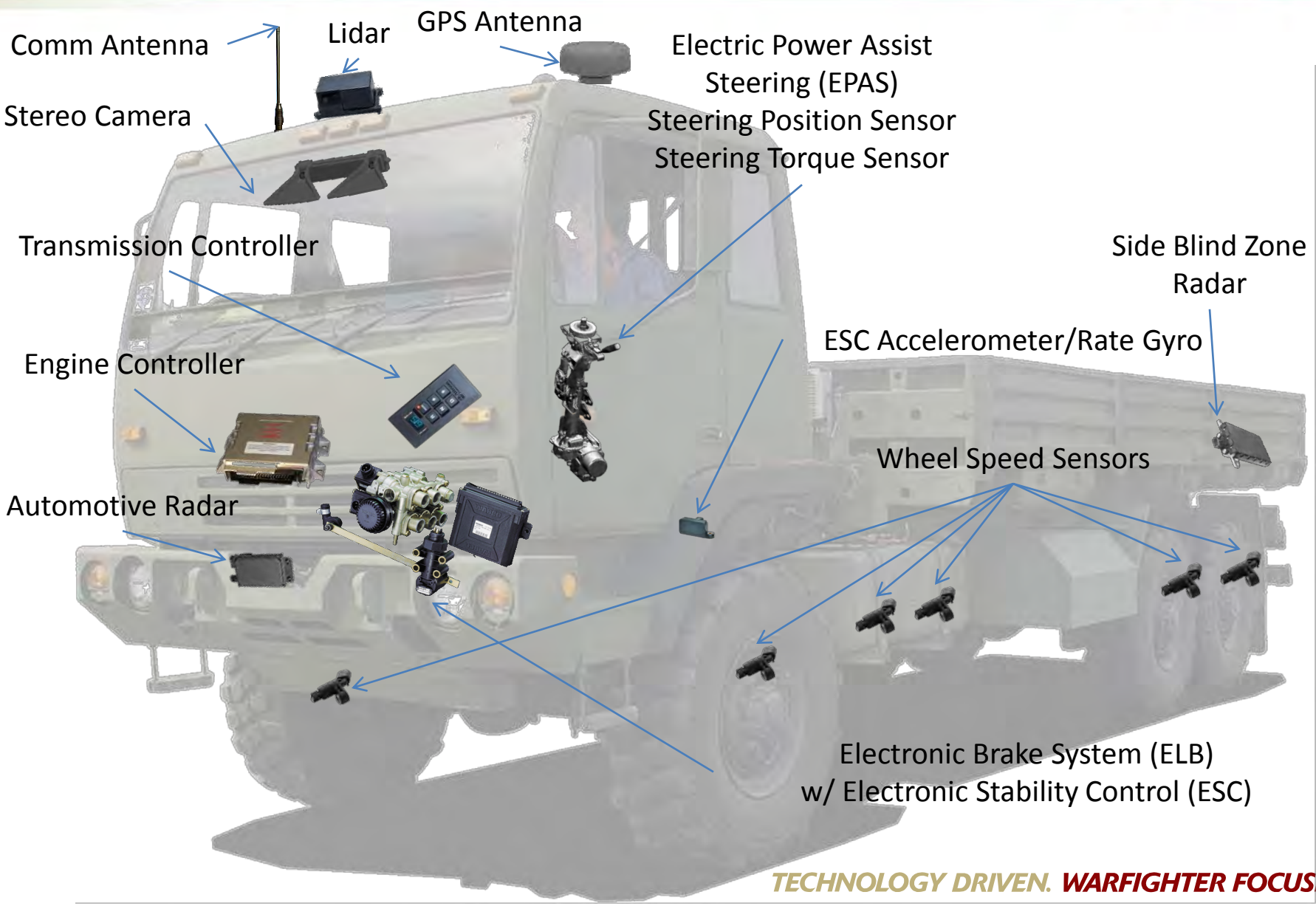
EBS Brake Controller

Wheel Speed Sensors

ESC Accelerometer /Rate Gyro

Engine Controller

Notional Implementation on FMTV

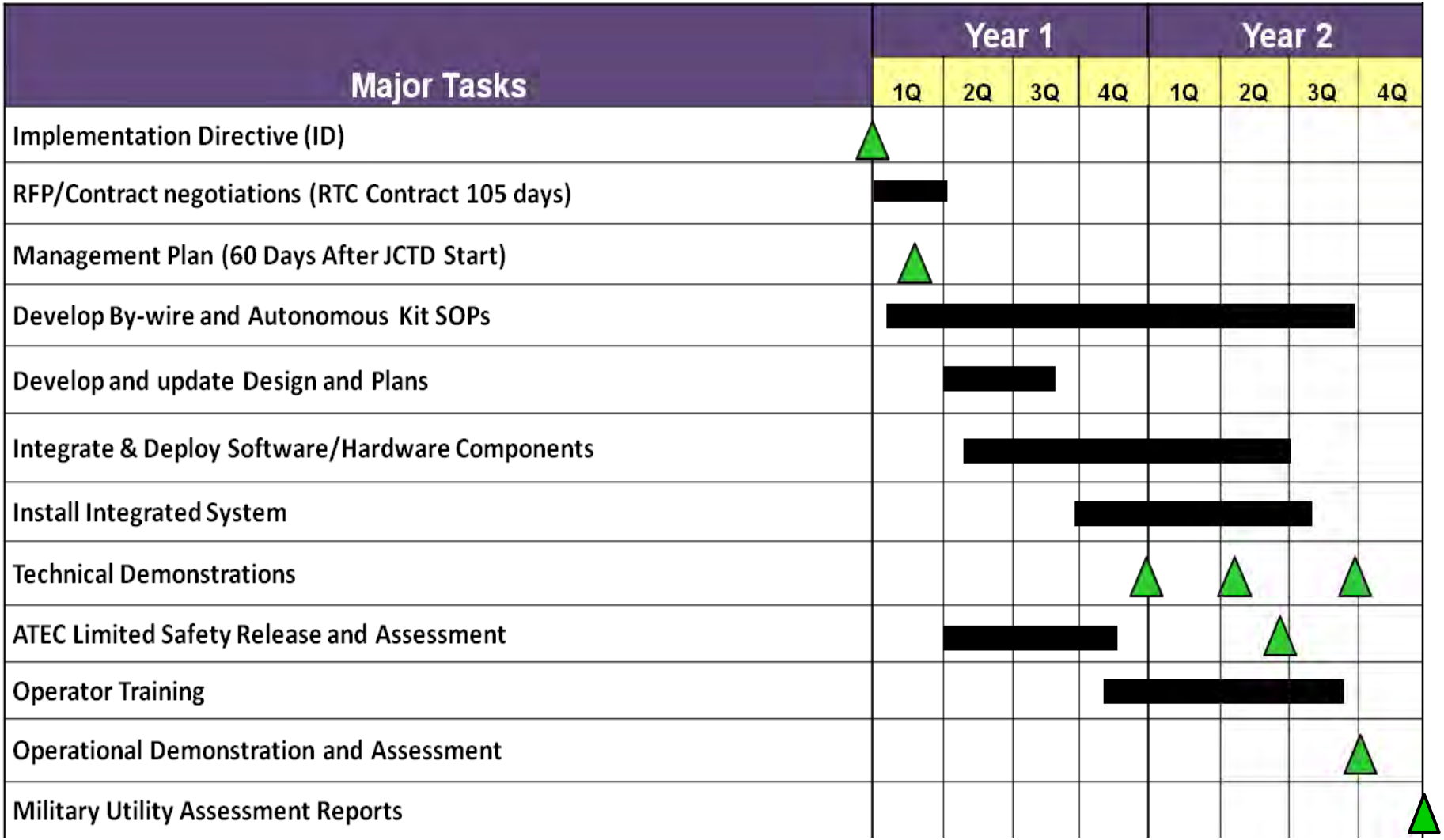


Capabilities of Scalable Autonomy

Level 1 Passive Driver Assist	Level 2 Active Driver Assist	Level 3 Automated Driving

• **Increase Situational Awareness**
  • Environment and Surroundings
  • Vehicle Capabilities and Configuration
• **Improved Safety**
  • Collision Warnings
  • Lane Departure Warnings
  • Tip Over Warnings
• **Reinforces Experienced drivers**
• **Increase Capabilities of inexperienced Drivers**
	• **Active Intervention**
	  • Maintain Lane Control
	  • Tip-Over Prevention
	  • Collision avoidance and mitigation
	  • Stability Control
	• **Enables operator to focus on other convoy mission tasks while the vehicle safely operates itself.**
		• **Leader/Follower Capabilities**
		  • Increase Operational Tempo
		  • Run faster with disciplined spacing
		  • Increased convoy capacity though unmanned vehicles
		• **Increase throughput and efficiencies**
		• **Dynamic planning and re-planning**
		  • Flexibility in convoy composition and routing
		  • Re-acquire route after dispersal
		  • Re-plan route to alternate

AMAS JCTD Schedule



Why AMAS JCTD

- Will Accelerate Transition of Technology to the Warfighter
  - AMAS JCTD is Directly Aligned with RS JPO's AMAS Initiative
  - JCTD will compress the Current RS JPO AMAS Program Schedule
  - Will define the Open Architecture and Interfaces standards for the AMAS program
  - Provide the Robotic System Joint Program Office (RS JPO) an investment Strategy for RDTE POR Funds.
  - Provide RS JPO with a Concept of Operations, TTP's, and testing methodology
- Joint Program
  - USMC has Significant Resources Invested
  - AMAS JCTD will Accelerate this Technology into Marine Platforms

AMAS JCTD Benefits for AMAS POR

- JCTD will compress AMAS Program Schedule
- Accelerate Technical Maturation
- Provide Open Architecture and Interfaces
- Standardized Metrics and Test Procedures
- Framework for Validation of Requirements
- Early identification of risk areas
  - Allows RS JPO to make informed decisions on where to invest RDTE POR dollars to reduce program risk
- Lessons Learned (Concept of Operations, TTP's, testing methodology)

The AMAS JCTD will provide Risk Reduction to the AMAS Program


TWVS ATO
GLASS CERAMIC
TRANSPARENT ARMOR
TARDEC
HERMIT
TARDEC

Questions?

CAST Overview

CAST addresses the operational need to project and sustain forces in distant, anti-access environments that pose challenges for combatant commanders.

CAST addresses new operational challenges, providing the ability to conduct sustainment convoy operations across operationally feasible times and distances on the battlefield.

By automating the driving function, operators are given an increased opportunity to raise awareness of their environment through scanning and surveillance, and vehicle systems have a decreased threat of collision.

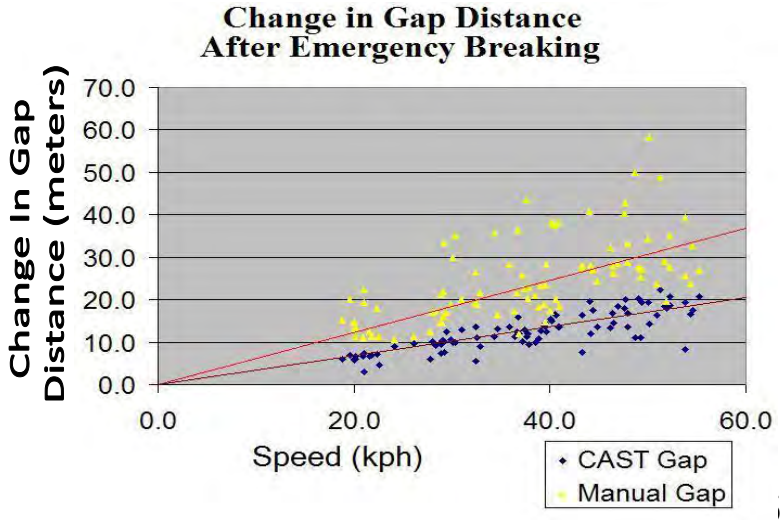
Convoy Active System Technology(CAST) Warfighter Experiment Results

Physiological Effects

- No reported central, peripheral, gastrointestinal motion sickness issues
- 20-25% increase in number of threat detections while CAST engaged
- 3-5 second increased response time
- Participants reported with significance less fatigue and ease of convoy execution while CAST engaged

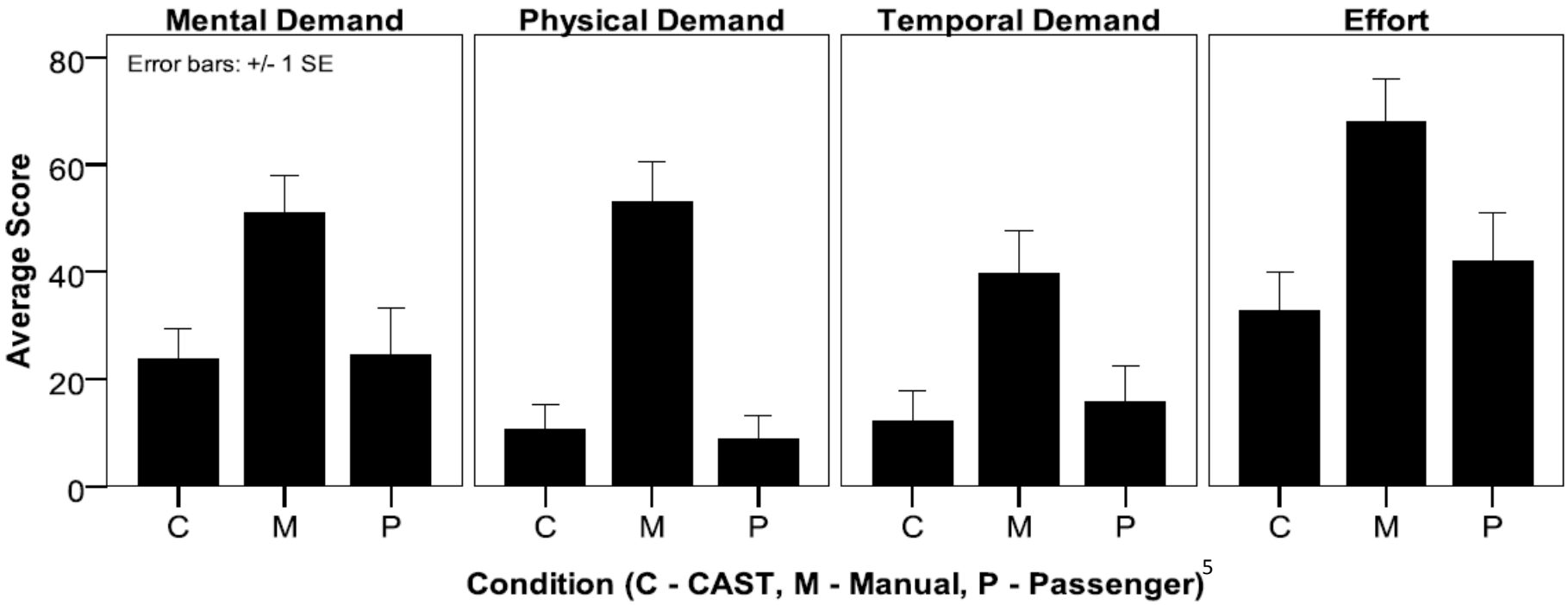
Vehicle System Performance

- Gap distance formation maintenance shows 150% improvement with CAST
- Cross track error consistency data shows 15% improvement with CAST
- Successful daylight driving at 85kph
- Successful blackout driving at 70kph
- Data shows 85% improvement in panic stopping distance with CAST



Convoy Capability Value
CAST Driver Workload Reduction

Average Friedman's Tests Scores for Three Conditions



[5]

Hart and Staveland's NASA Task Load Index (TLX):

- **Mental Demand:** How mentally demanding was the task
- **Physical Demand:** How physically demanding was the task
- **Temporal Demand:** How hurried or rushed was the pace of the task
- **Effort:** How hard did you have to work to accomplish your level of performance

References

1. Concurrent Technology Corporation (CTC). (Jan 25,2011). *Identification of Military Vehicle Accidents Causes Preventable by Safety Technology.* Washington DC: Office of the Secretary of Defense Readiness Programming and Assessment.

2. RAND. (Oct 2011). Draft Study on *Assessing the Impact of Autonomous Robotic Systems on Army Force Structure.* ARCIC.

3. Center for AMEDD Strategic Studies.(March 2011).*Defense Casualty Information System Compendium of US Army Injuries from Operation Iraqi Freedom and Operation Enduring Freedom*, October 2001 - December 2010.

4. CASCOM CCD Concepts Division.(Sep 2011). *Draft Calculations for AMAS CDD Cost Benefit Analysis*. CASCOM.

5. Lockheed Martin Corporation.(Oct 2011). *Effects of the Convoy Active Safety Technologies (CAST) System on Driver Workload.* TARDEC

6. Assumption - Work is ongoing to quantify cost and benefit. This statements are based on the performance increases observed . No data is readily available or it cannot be easily measured.

7. PEO CS&CSS.(Dec 2007)*Perspective on Condition Based Maintenance*.PM Tactical Vehicle

8. NDIA.(Aug 2008) *Fully Burdened Cost of Fuel Methodology and Calculations for Ground Forces. NDIA Fully Burdened Cost of Fuel Workshop*. NDIA Energy and Security Group

9. Based on 17 responses received from AMAS JCTD RFI.

10. Based of TARDEC's Engineering Estimates.

11. Based on Safety Center numbers over 10 Year period for Class A,B, and C Accidents in CONUS and Theater. Total Damage Cost equaled 177 Million for all 3 accident categories. Assumed 100% indirect cost for recovery and labor. See Calculations.